THE INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY

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THE EFFECT OF MOISTURE CONTENT ON RING CRUSH AND SHORT SPAN COMPRESSIVE STRENGTH

IPST Project 3817

A Summary Report

to

THE CONTAINERBOARD AND KRAFT PAPER GROUP

OF THE

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THE EFFECT OF MOISTURE CONTENT ON RING CRUSH AND SHORT SPAN COMPRESSIVE STRENGTH

EXECUTIVE SUMMARY

This report presents the results of a study aimed at (1) defining the relationship between moisture content and compressive strength of linerboard and corrugating medium, and (2) determining whether the relationship is effected by type or source of the sample.

Thirty five samples were collected from member mills of CKPG. These included three weights each of standard liner and medium, recycled and HP liner and medium, and green liquor medium. The samples came from both east and west coast mills.

The samples were tested at relative humidities of 20, 30, 40, 50, 60, 70, and 80%. At each humidity the samples were tested for moisture content, CD ring crush, and CD short span compression (STFI).

The results show that:

1. Over the range of 20 to 60% relative humidity, a linear relationship exists between CD ring crush and moisture content. Within this range CD ring crush decreases 5% for an increase of 1% moisture content. Above 60% relative humidity, the rate of decrease gradually accelerates.

2. Over the range of 20 to 60% relative humidity, a linear relationship exists between CD STFI and moisture content. Within this range CD STFI decreases 7% for an increase of 1% moisture content. Above 60% relative humidity, the rate of decrease gradually accelerates.

3. There is nothing in the data to suggest that the above values (5% for ring crush and 7% for STFI) are significantly different for samples of different types or obtained from different sources.

INTRODUCTION

The published literature contains little information on the relationship between moisture content and compressive strength of linerboard and corrugating medium. The few references found give data for different relative humidities, but do not include moisture content; nor do they include data for the newer short span (STFI) compressive strength test. These studies also did not include the newer HP grades nor those made with recycled fibers.

This study was undertaken to more accurately define the relationship, and to determine whether that relationship is effected by the type or source of sample.

The samples were tested for moisture content, CD ring crush, and CD STFI at relative humidities of 20, 30, 40, 50, 60, 70, and 80%. The type and source of samples, testing procedures, test results, and calculated relationships between moisture content and compressive strength are given in the following sections of this report.

SAMPLES

Member mills of CKPG were invited to submit samples for the study. Thirty five samples were collected. The type and source of these is given below.

	Number of Samples
33 LB Linerboard	4
42 LB Linerboard	4
69 LB Linerboard	4
42 LB Recycled Linerboard	2
HP-D Linerboard	3
26 LB Medium	4
33 LB Medium	3
40 LB Medium	3
26 LB Green Liquor Medium	2
26 LB Recycled Medium	3
HP-R Medium	3

Of the above samples, 28 were from east coast mills and 7 from west coast mills.

TESTING PROCEDURES

Each of the samples was cut into sufficient specimens to permit 25 CD ring crush and 25 CD STFI tests at each of seven different relative humidities. The cut specimens were then thoroughly mixed to obtain a random sample for testing at each humidity. A separate moisture specimen was cut from each sample.

All of the specimens were initially preconditioned for at least 24 hours at a relative humidity of 10% and a temperature of 23 degrees C. The random samples were then conditioned at least 48 hours at the testing relative humidities of either 20, 30, 40, 50, 60, 70, or 80%, all at a temperature of 23 degrees C.

The same moisture specimen for each sample was used throughout the testing. The specimen was conditioned with each group of compressive test specimens at each humidity in accending order of humidities. After all compressive tests were completed, the oven dry weights of the moisture specimens were determined. Moisture contents were then calculated based on air dry weights at each relative humidity.

Ring crush tests were made using a rigid platen tester in accord with TAPPI method T822 om-89. STFI tests were made in accord with TAPPI method T826 om-86. In each case, twenty five tests were made to obtain an average value.

TEST RESULTS

Relative Humidity - Moisture Content Relationship

The moisture contents for each sample at each relative humidity are given in the Appendix. The average moisture contents for different sample catagories are given is Table I. A plot of moisture content vs relative humidity is shown in Figure 1.

The only cases in which the number of samples are large enough to permit statistical analysis of differences are those for all liners combined, all mediums combined, east coast samples and west coast samples. The data in Table I clearly show that there is no significant difference between the average moisture content of east and west coast samples. The data also show that the average moisture content of linerboard samples is a little higher than that of medium samples, and this difference is statistically significant at the .05 probability level. The data for these is shown plotted separately in Figure 1.

There are other groups of samples for which moisture content differences may exist. The moisture content for recycled medium, for example, is clearly higher than that for other medium types. However, the sample size is too small to draw any valid statistical conclusions regarding the difference.

Table I
The Effect of Relative Humidity on Moisture Content

Sample Lot Description	Number of Samples	Relative Humidity, % 20	30	40	50	60	70	80
		Moisture Content, %						
All Samples	35	4.20	5.50	6.59	7.51	8.61	9.97	12.00
All Liner	17	4.32	5.66	6.76	7.59	8.76	10.21	12.31
All Medium	18	4.08	5.36	6.42	7.44	8.46	9.75	11.69
All West Coast	7	4.19	5.48	6.57	7.56	8.65	10.01	11.84
All East Coast	28	4.20	5.51	6.59	7.50	8.59	9.96	12.03
All 33# Liner	4	4.29	5.64	6.78	7.63	8.87	10.36	12.51
All 42# Liner	4	4.26	5.62	6.77	7.52	8.71	10.15	12.20
All 69# Liner	4	4.35	5.68	6.75	7.49	8.74	10.19	12.38
All Recy Liner	2	4.40	5.69	6.76	7.52	8.60	9.96	12.00
All HP Liner	3	4.34	5.67	6.72	7.81	8.78	10.27	12.33
All 26# Medium	4	4.07	5.32	6.32	7.27	8.38	9.68	11.68
All 33# Medium	3	4.04	5.32	6.35	7.39	8.38	9.61	11.58
All 40# Medium	3	3.90	5.26	6.36	7.37	8.34	9.55	11.57
All Gr Liq Medium	2	3.98	5.19	6.29	7.36	8.31	9.42	11.33
All Recy Medium	3	4.28	5.65	6.74	7.79	8.88	10.24	12.36
All HP Medium	3	4.18	5.36	6.47	7.46	8.47	9.90	11.53

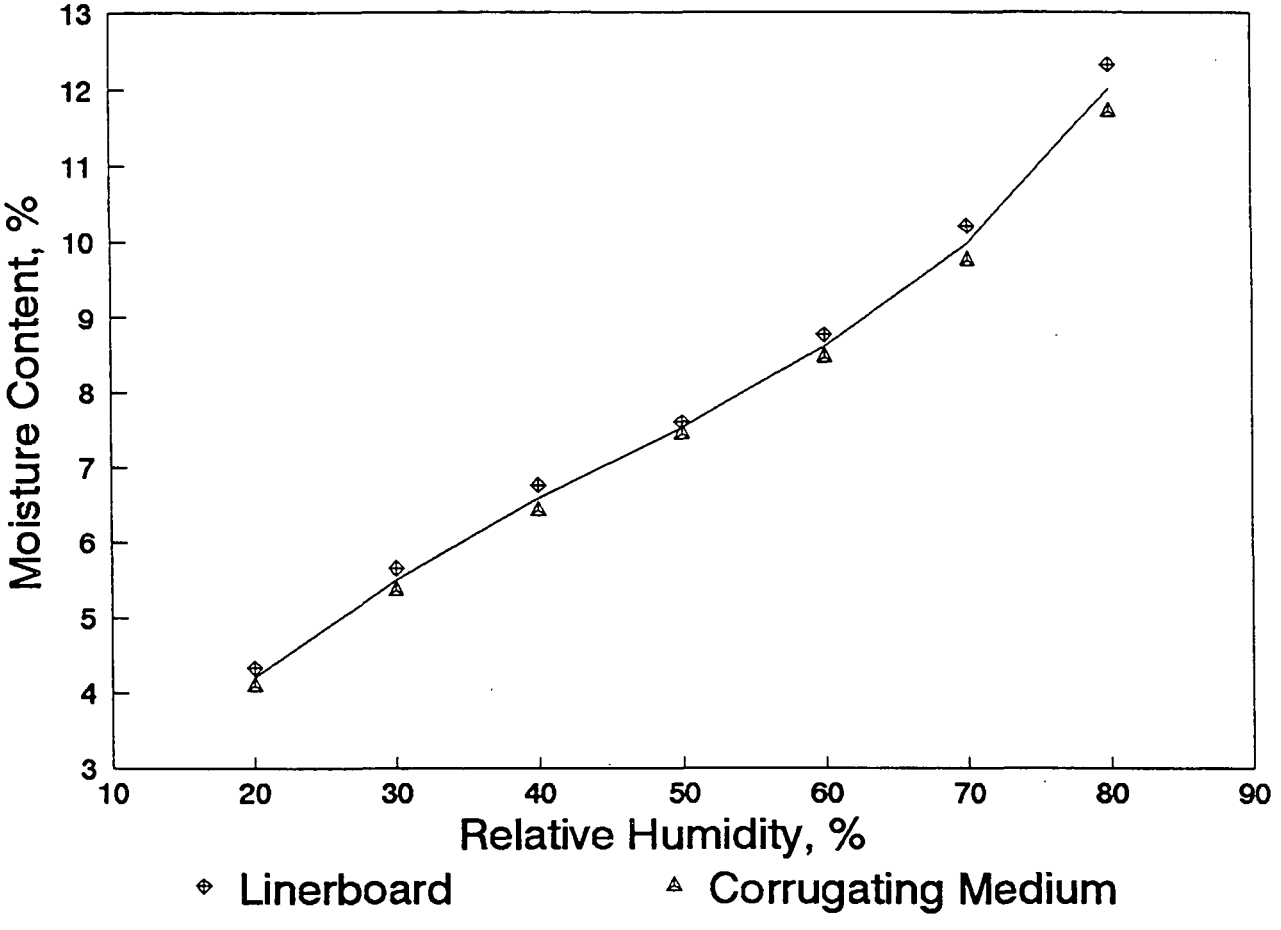


Figure 1. The relationship between relative humidity and moisture content (the solid liner represents averages for all samples combined).

Compressive Strength - Moisture Content Relationships

The test results for each individual sample are given in the Appendix. The results given for each sample and relative humidity include the average and standard deviation of ring crush, the ratio of this average to that obtained at 50% relative humidity, the average and standard deviation of STFI, the ratio of this average to that obtained at 50% relative humidity, and the measured moisture content.

Plots of the data for various groups of samples are shown in Figures 2a through 8b. In each case, the compressive strength (ring crush or STFI) is plotted as the ratio of strength at the measurement RH to the strength at 50% RH.

Figures 2a and 2b show the results for all samples combined. Regression analyses of these data were made and the results are given in Table II. Four different analyses were made. These included all data between 20 and 50% RH, 20 and 60% RH, 20 and 70% RH, and 20 and 80% RH, respectively. The results clearly show that there is a linear relationship between ring crush and moisture content, and between STFI and moisture content, in the relative humidity range of 20 to 60%, and that both relationships depart from linearity above 60% RH.

Based on the results given in Table II and shown in Figs. 2a and 2b, it is concluded that, in the range of 4 to about 9% moisture content, the STFI compressive strength decreased 7% for each 1% increase in moisture content. Over the same range, the ring crush decreases about 5%.

Figures 3a through 8b show relationships between compressive strength and moisture content for different types of samples. In each case, the symbols represent averages for the types of samples indicated, and the solid line represents the average for all samples included in the study.

The number of samples included in each type is too small to permit any valid statistical analysis. However, there is nothing in the plots shown in Figs. 3a through 8b to suggest that the above values (5% for ring crush and 7% for STFI) are significantly different for samples of different types or obtained from different sources.

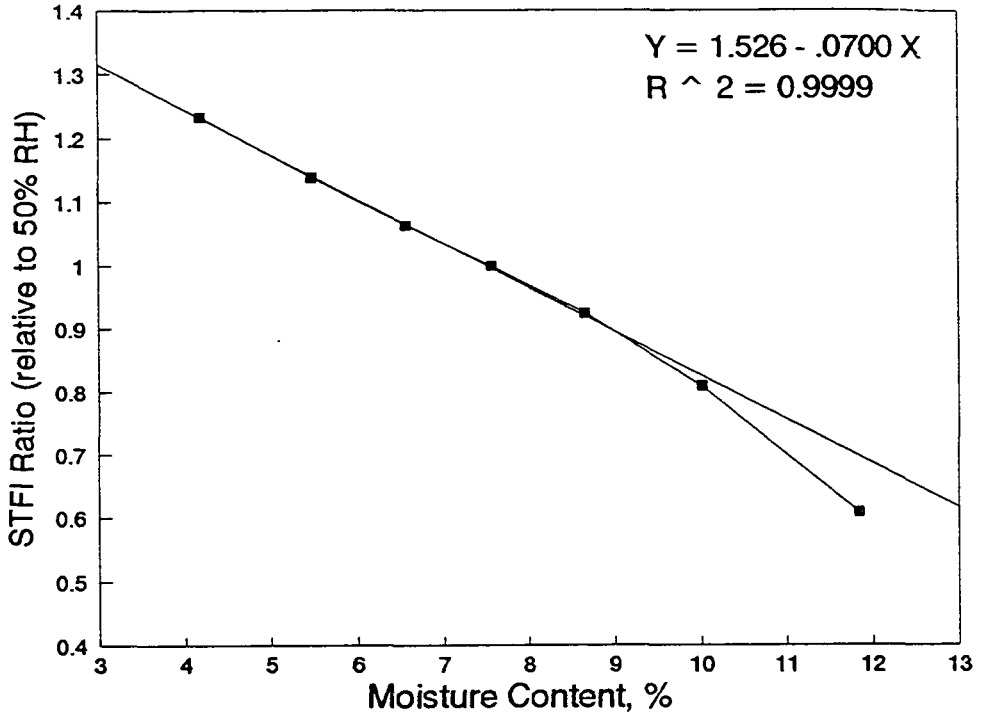


Figure 2a. The effect of moisture content on STFI for all grades.

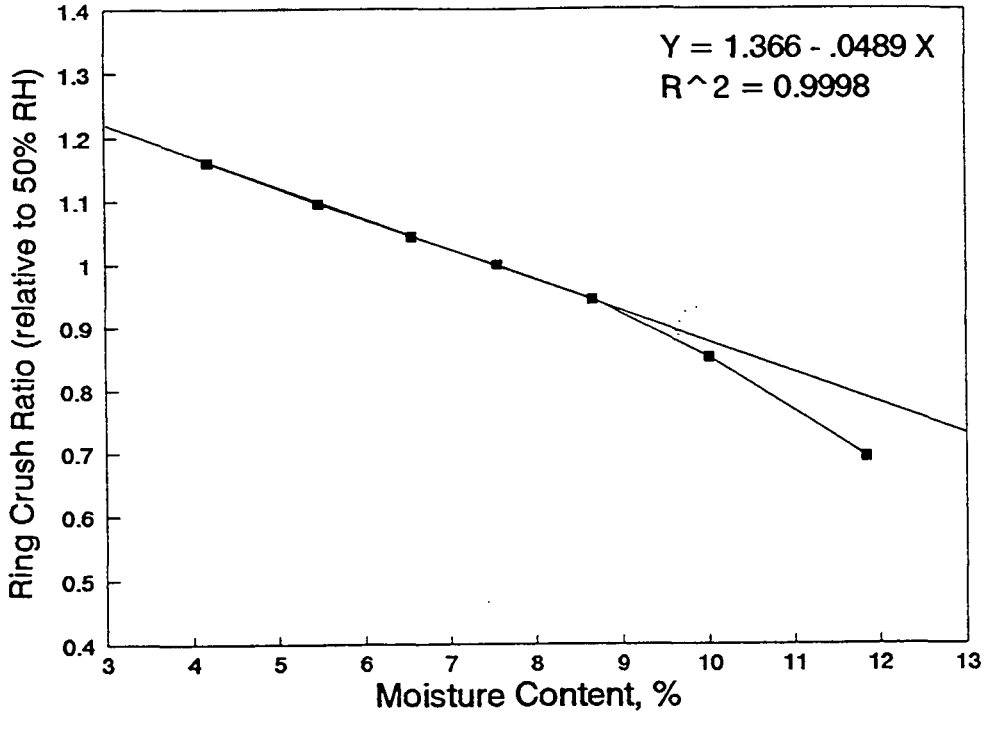


Figure 2b. The effect of moisture content on ring crush for all grades.

Table II
Regression Analysis for all Data

X = Moisture Y = Ring Crush X = Moisture Y = STFI

(20 to 50 % R.H.)

Regression Output:		Regression Output:	
Constant	1.3631	Constant	1.5283
Std Err of Y Est	0.0009	Std Err of Y Est	0.0013
R Squared	0.9999	R Squared	0.9999
No. of Observations	4	No. of Observations	4
Degrees of Freedom	2	Degrees of Freedom	2
X Coefficient(s)	-0.0484	X Coefficient(s)	-0.0705
Std Err of Coef.	0.0004	Std Err of Coef.	0.0005

(20 to 60 % R.H.)

Regression Output:		Regression Output:	
Constant	1.3658	Constant	1.5261
Std Err of Y Est	0.0012	Std Err of Y Est	0.0014
R Squared	0.9998	R Squared	0.9999
No. of Observations	5	No. of Observations	5
Degrees of Freedom	3	Degrees of Freedom	3
X Coefficient(s)	-0.0489	X Coefficient(s)	-0.0700
Std Err of Coef.	0.0004	Std Err of Coef.	0.0004

(20 to 70 % R.H.)

Regression Output:		Regression Output:	
Constant	1.3859	Constant	1.5414
Std Err of Y Est	0.0088	Std Err of Y Est	0.0067
R Squared	0.9949	R Squared	0.9984
No. of Observations	6	No. of Observations	6
Degrees of Freedom	4	Degrees of Freedom	4
X Coefficient(s)	-0.0524	X Coefficient(s)	-0.0727
Std Err of Coef.	0.0019	Std Err of Coef.	0.0014

(20 to 80 % R.H.)

Regression Output:		Regression Output:	
Constant	1.4261	Constant	1.5801
Std Err of Y Est	0.0206	Std Err of Y Est	0.0193
R Squared	0.9858	R Squared	0.9930
No. of Observations	7	No. of Observations	7
Degrees of Freedom	5	Degrees of Freedom	5
X Coefficient(s)	-0.0588	X Coefficient(s)	-0.0788
Std Err of Coef.	0.0032	Std Err of Coef.	0.0030

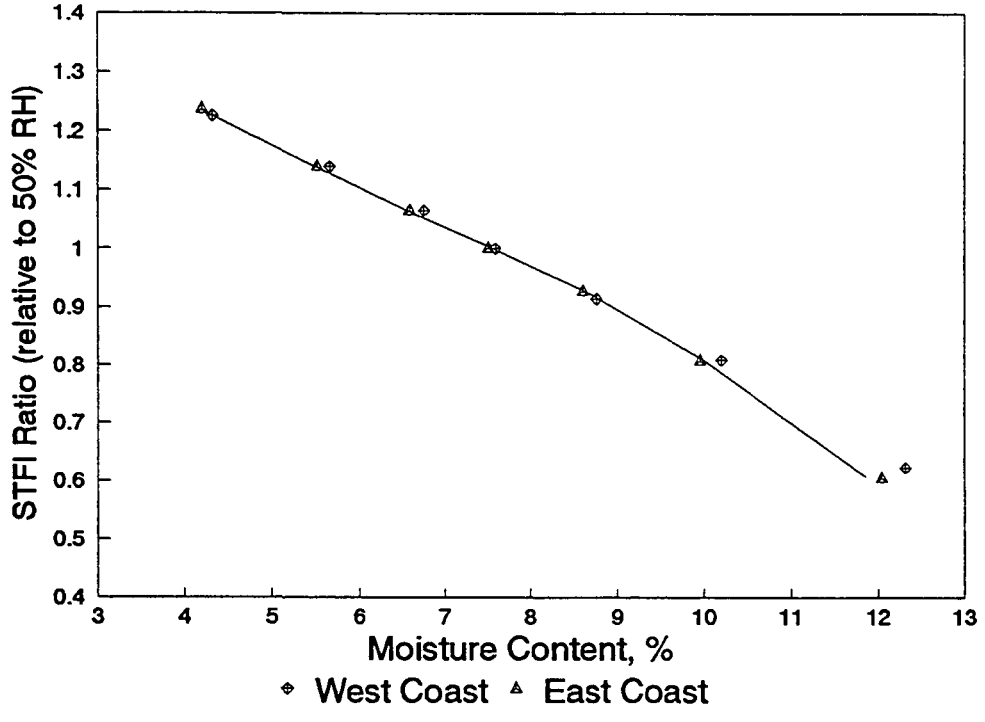


Figure 3a. The effect of moisture content on STFI for different geographical areas.

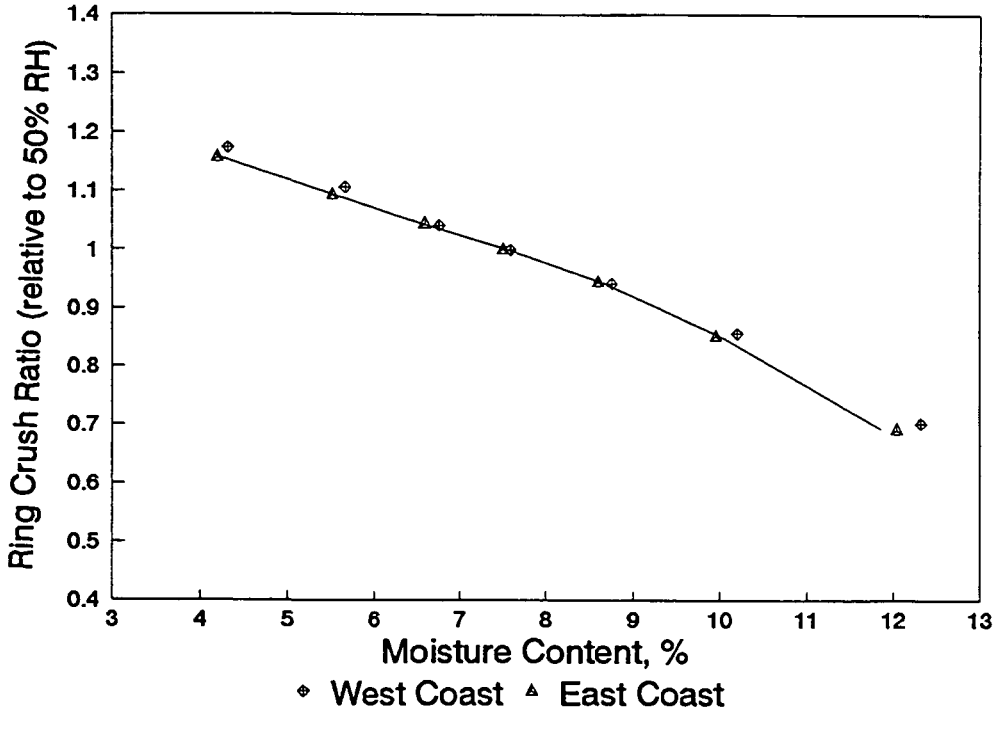


Figure 3b. The effect of moisture content on ring crush for grades by geographical areas.

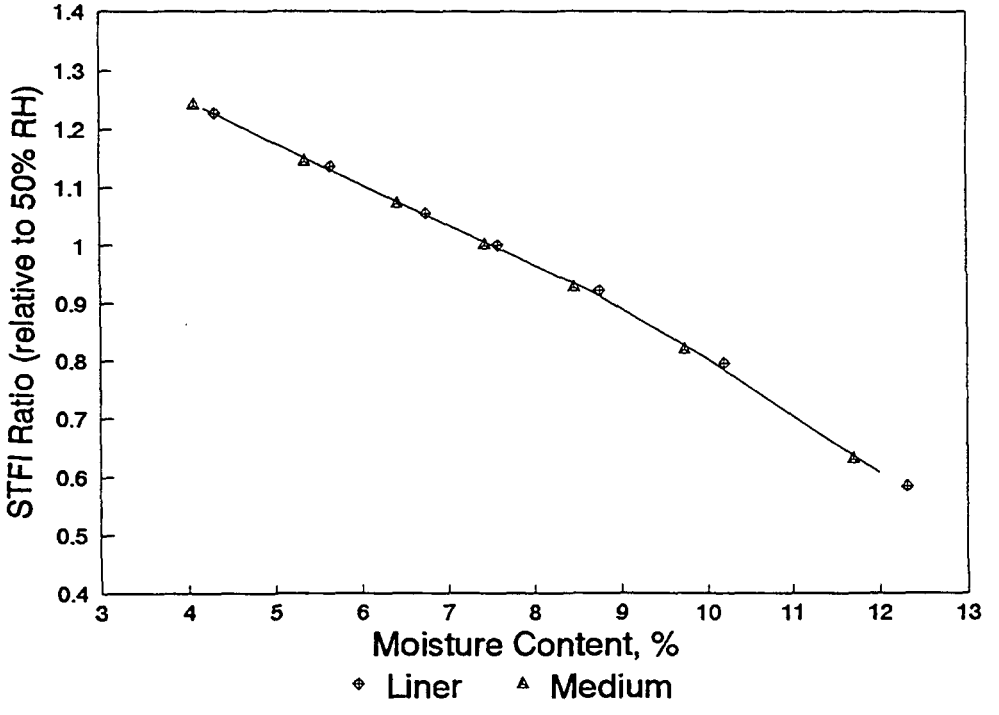


Figure 4a. The effect of moisture content on STFI for liner and medium separately.

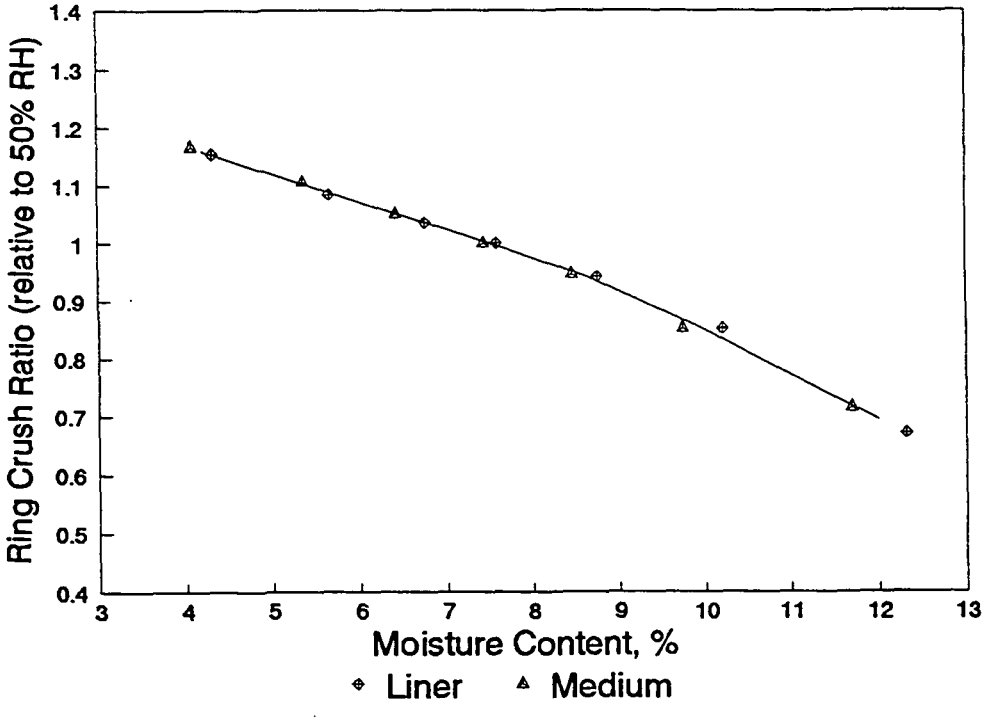


Figure 4b. The effect of moisture content on ring crush for liner and medium separately.

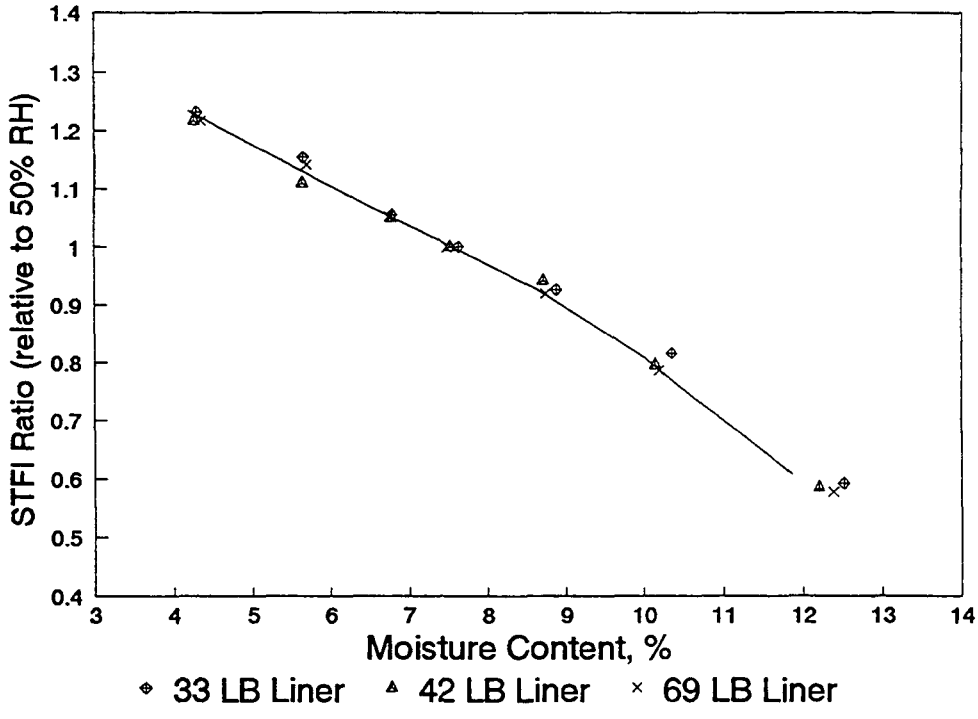


Figure 5a. The effect of moisture content on STFI for liner by basis weight.

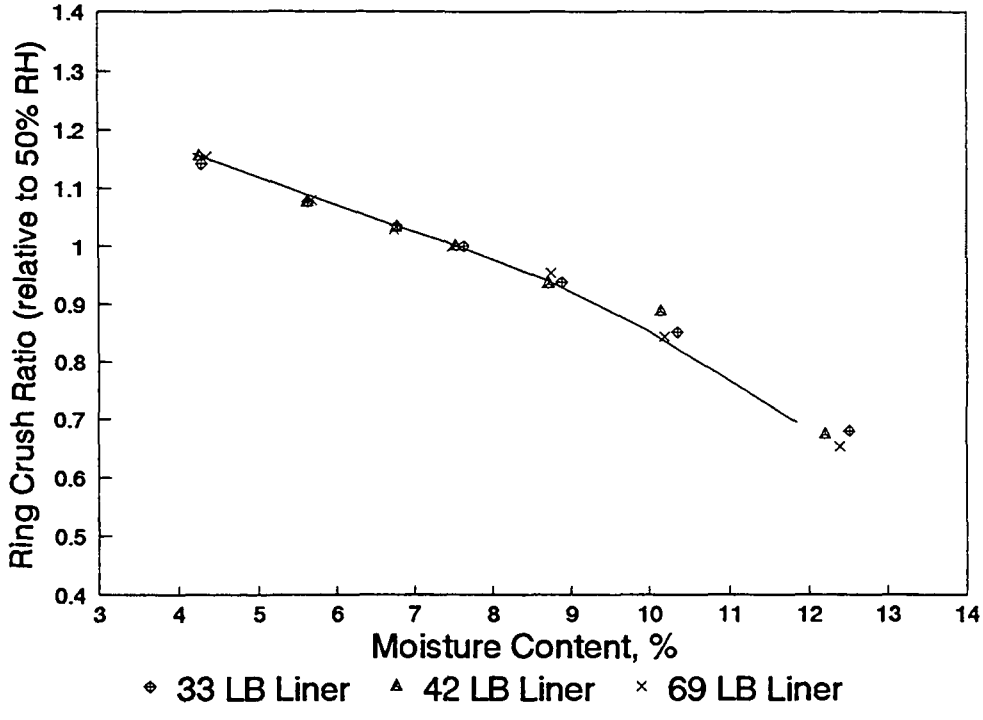


Figure 5b. The effect of moisture content on ring crush for liner by basis weight.

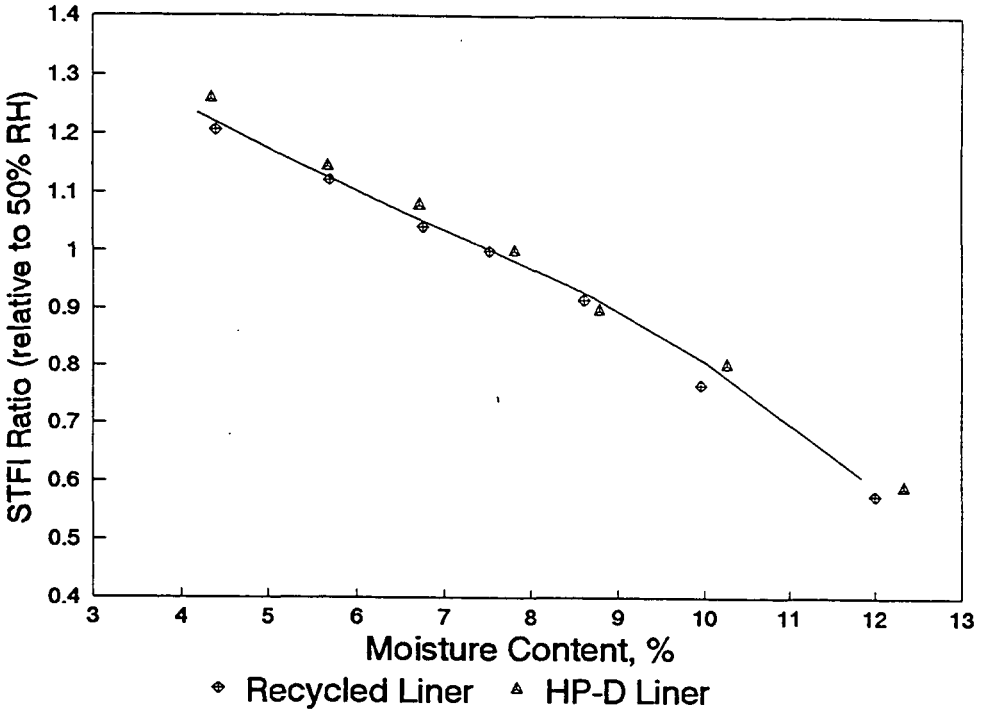


Figure 6a. The effect of moisture content on STFI for recycled and HP liner.

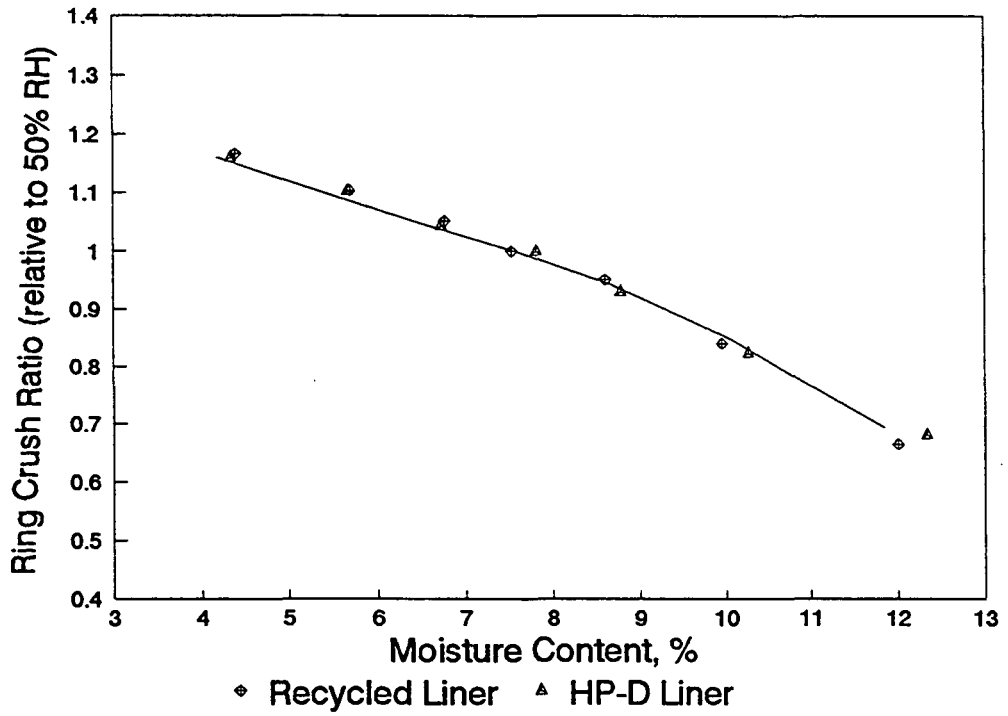


Figure 6b. The effect of moisture content on ring crush for recycled and HP liner.

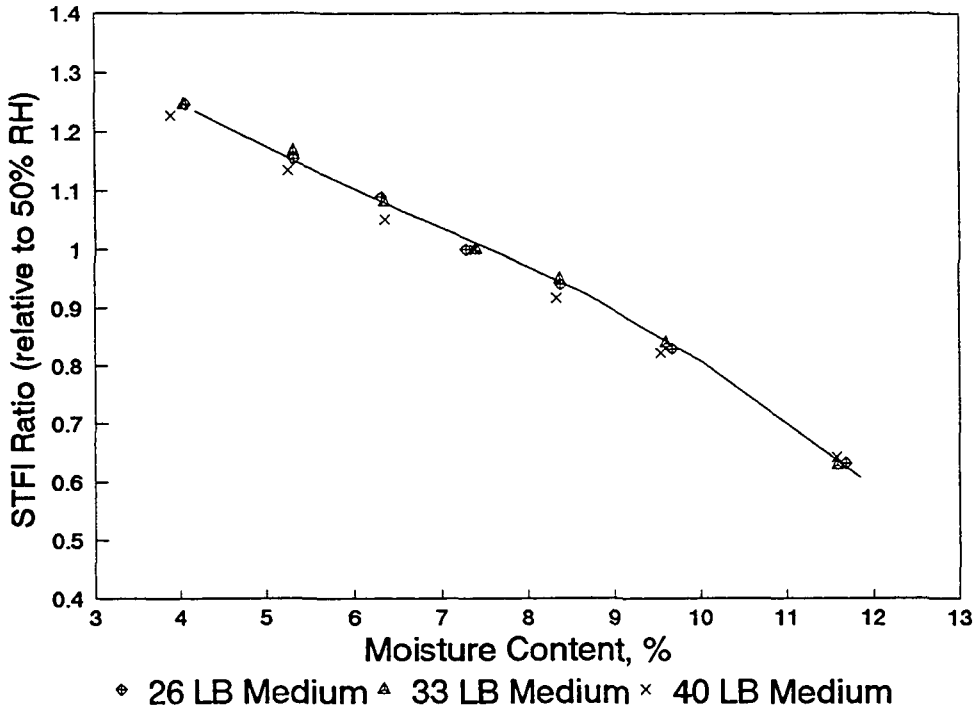


Figure 7a. The effect of moisture content on STFI for medium by basis weight.

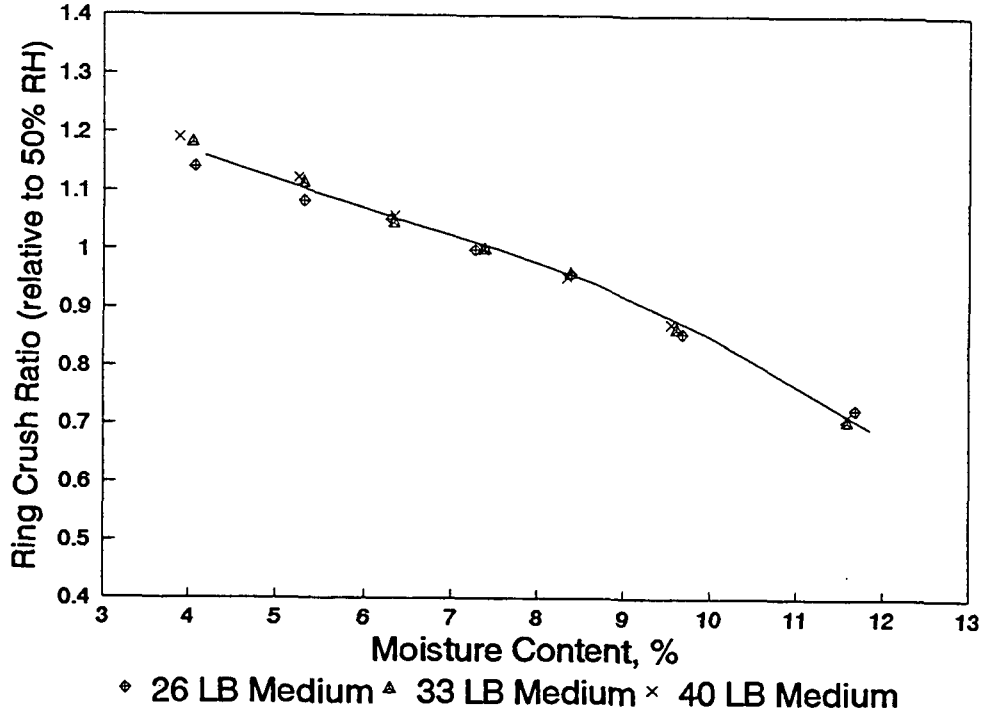


Figure 7b. The effect of moisture content on ring crush for medium by basis weight.

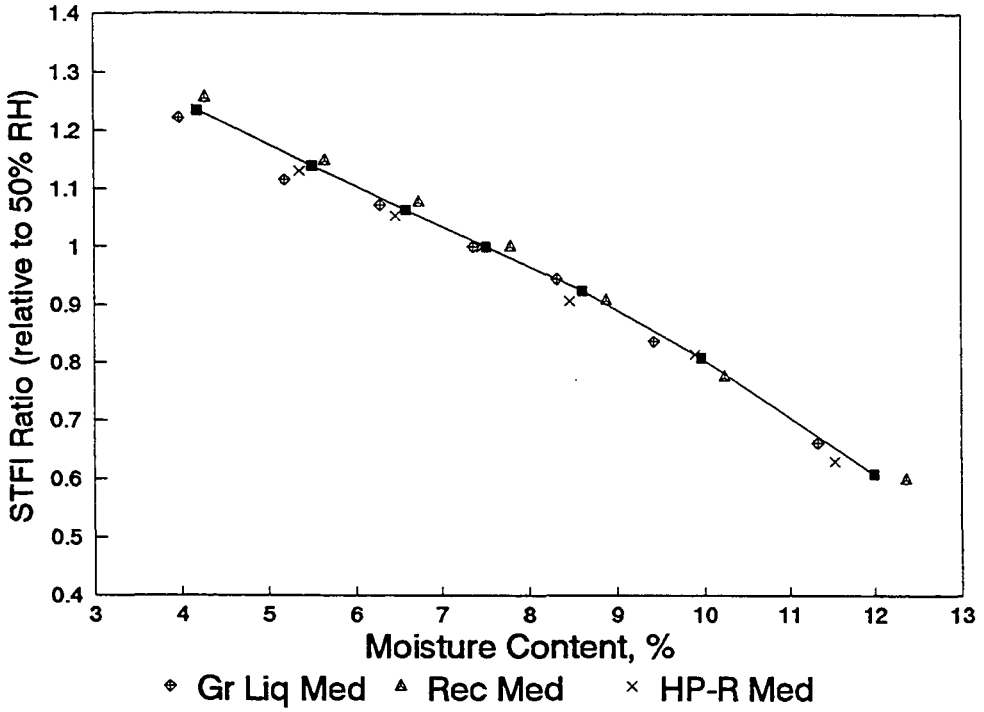


Figure 8a. The effect of moisture content on STFI for green liquor, recycled and HP medium.

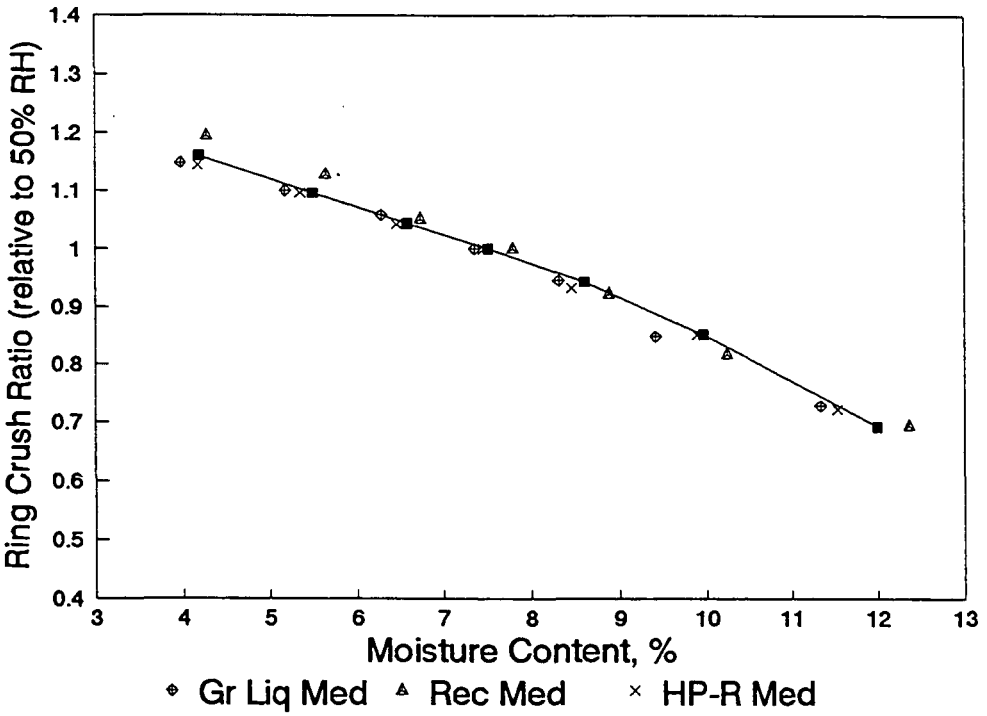


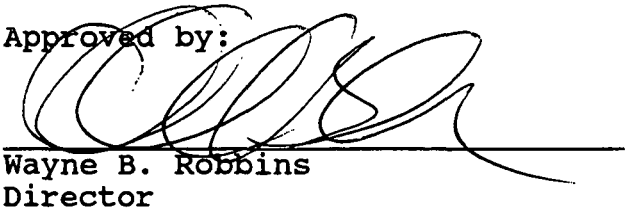
Figure 8b. The effect of moisture content on ring crush for green liquor, recycled and HP medium.

The Institute of Paper Science and Technology
Atlanta, Georgia

Submitted by:

Roger H. Van Eperen
Principal Investigator

Approved by:



Wayne B. Robbins
Director
Research Services Division

Effect of Relative Humidity on Ring Crush, STFI, and Moisture Content

Percent R.H.	20%	30 %	40 %	50 %	60%	70%	80%
Sample Name = 42 lb liner East Coast							
Ring Crush, lbs	105.9	98.1	96.2	90.7	85.8	80.8	62.0
Std. Dev.	7.32	7.66	7.30	6.78	4.37	4.87	4.61
Ratio to 50%	1.167	1.082	1.061	1.000	0.946	0.890	0.684
STFI, lb/in	29.0	27.8	25.8	24.8	22.4	20.0	14.4
Std. Dev.	3.07	3.08	2.38	2.64	1.93	2.61	1.32
Ratio to 50%	1.169	1.121	1.042	1.000	0.903	0.805	0.581
Moisture, %	4.49	5.90	7.07	7.64	8.84	10.22	12.13
Sample Name = 42 lb liner East Coast							
Ring Crush, lbs	97.6	91.8	89.5	86.8	79.0	75.8	56.9
Std. Dev.	8.63	8.95	6.27	6.11	6.25	6.62	5.09
Ratio to 50%	1.124	1.057	1.031	1.000	0.910	0.873	0.655
STFI, lb/in	28.8	23.8	23.7	22.3	21.1	17.0	12.9
Std. Dev.	2.32	2.48	2.20	2.25	1.33	1.29	1.33
Ratio to 50%	1.293	1.070	1.067	1.000	0.947	0.765	0.578
Moisture, %	4.23	5.62	6.77	7.53	8.70	10.26	12.40
Sample Name = 42 lb liner West Coast							
Ring Crush, lbs	91.9	83.2	78.9	76.4	73.4	70.8	51.7
Std. Dev.	8.87	7.29	7.09	7.88	6.49	5.99	4.25
Ratio to 50%	1.202	1.088	1.032	1.000	0.960	0.926	0.677
STFI, lb/in	25.2	23.4	21.6	20.8	20.5	17.4	12.2
Std. Dev.	2.64	2.77	2.62	2.29	1.27	2.20	1.67
Ratio to 50%	1.211	1.125	1.038	1.000	0.983	0.835	0.585
Moisture, %	4.21	5.54	6.64	7.51	8.65	9.99	12.01
Sample Name = 42 lb liner East Coast							
Ring Crush, lbs	100.1	95.4	88.9	88.6	82.1	76.2	59.9
Std. Dev.	7.10	5.06	5.37	6.07	4.29	4.05	2.60
Ratio to 50%	1.129	1.076	1.002	1.000	0.926	0.859	0.676
STFI, lb/in	27.7	26.0	24.3	23.2	21.6	18.0	13.7
Std. Dev.	3.01	2.36	2.10	2.29	2.16	1.55	1.33
Ratio to 50%	1.195	1.122	1.049	1.000	0.932	0.777	0.590
Moisture, %	4.12	5.44	6.61	7.41	8.64	10.11	12.25

Effect of Relative Humidity on Ring Crush, STFI, and Moisture Content

Percent R.H.	20%	30 %	40 %	50 %	60%	70%	80%
Sample Name =	33 lb liner				East Coast		
Ring Crush, lbs	81.5	77.1	73.4	70.5	67.2	61.4	47.4
Std. Dev.	5.56	8.64	4.20	4.48	4.79	5.42	3.41
Ratio to 50%	1.155	1.093	1.041	1.000	0.953	0.871	0.672
STFI, lb/in	24.4	22.9	21.8	20.0	19.1	16.2	11.7
Std. Dev.	2.14	1.81	2.41	1.71	1.81	1.45	1.22
Ratio to 50%	1.220	1.150	1.090	1.000	0.956	0.813	0.588
Moisture, %	4.39	5.65	6.88	7.72	8.92	10.38	12.50
Sample Name =	33 lb liner				East Coast		
Ring Crush, lbs	81.9	77.5	73.3	72.8	67.7	62.6	47.9
Std. Dev.	5.52	6.46	5.35	3.75	7.71	3.91	2.79
Ratio to 50%	1.125	1.064	1.007	1.000	0.929	0.859	0.658
STFI, lb/in	25.0	22.9	21.8	21.0	18.8	15.9	11.5
Std. Dev.	1.83	1.93	1.86	1.71	1.74	1.24	1.07
Ratio to 50%	1.188	1.089	1.036	1.000	0.894	0.758	0.548
Moisture, %	4.27	5.77	6.80	7.75	9.00	10.47	12.64
Sample Name =	33 lb liner				East Coast		
Ring Crush, lbs	73.2	68.2	67.0	64.6	61.3	54.4	44.0
Std. Dev.	3.69	5.75	3.85	3.50	2.72	4.14	1.99
Ratio to 50%	1.133	1.056	1.038	1.000	0.949	0.842	0.681
STFI, lb/in	24.6	23.0	20.0	19.3	18.0	14.9	10.9
Std. Dev.	2.51	1.95	1.67	1.79	1.26	1.12	0.86
Ratio to 50%	1.277	1.190	1.037	1.000	0.932	0.773	0.567
Moisture, %	4.30	5.60	6.77	7.50	8.71	10.30	12.42
Sample Name =	33 lb liner				East Coast		
Ring Crush, lbs	73.6	69.6	66.8	63.6	58.5	53.0	45.0
Std. Dev.	8.55	7.65	5.65	9.09	6.55	6.19	4.06
Ratio to 50%	1.156	1.093	1.050	1.000	0.919	0.832	0.708
STFI, lb/in	21.4	20.5	18.2	17.2	15.9	15.9	11.4
Std. Dev.	3.05	3.72	2.30	2.79	2.75	1.98	1.35
Ratio to 50%	1.242	1.187	1.056	1.000	0.922	0.921	0.662
Moisture, %	4.20	5.54	6.68	7.57	8.86	10.27	12.47

Effect of Relative Humidity on Ring Crush, STFI, and Moisture Content

Percent R.H.	20%	30 %	40 %	50 %	60%	70%	80%
Sample Name =	69 lb liner				East Coast		
Ring Crush, lbs	163.4	149.2	143.1	139.8	134.1	120.0	90.0
Std. Dev.	8.90	9.37	10.22	7.40	7.22	7.08	6.64
Ratio to 50%	1.169	1.068	1.024	1.000	0.960	0.859	0.644
STFI, lb/in	41.4	39.4	36.5	35.1	31.2	27.7	19.8
Std. Dev.	5.01	3.36	3.52	3.23	3.42	2.79	1.88
Ratio to 50%	1.180	1.123	1.042	1.000	0.890	0.790	0.565
Moisture, %	4.25	5.51	6.58	7.25	8.42	9.92	12.06
Sample Name =	69 lb liner				East Coast		
Ring Crush, lbs	149.1	141.6	137.1	130.8	124.9	111.0	88.2
Std. Dev.	10.32	8.37	7.74	7.87	6.12	6.21	3.71
Ratio to 50%	1.140	1.083	1.048	1.000	0.955	0.849	0.675
STFI, lb/in	38.0	36.4	33.2	31.2	29.4	25.2	18.8
Std. Dev.	4.17	3.80	2.49	3.17	2.71	2.23	1.64
Ratio to 50%	1.218	1.165	1.065	1.000	0.942	0.807	0.602
Moisture, %	4.45	5.80	6.78	7.59	9.02	10.42	12.62
Sample Name =	69 lb liner				East Coast		
Ring Crush, lbs	173.9	161.2	147.7	147.3	140.3	124.0	94.9
Std. Dev.	8.45	8.10	8.20	6.96	4.78	5.18	6.97
Ratio to 50%	1.180	1.094	1.002	1.000	0.952	0.842	0.644
STFI, lb/in	41.7	38.3	34.6	33.5	31.0	25.5	18.7
Std. Dev.	4.14	3.78	3.70	3.51	2.60	2.67	1.96
Ratio to 50%	1.242	1.142	1.032	1.000	0.925	0.761	0.558
Moisture, %	4.34	5.69	6.81	7.59	8.79	10.22	12.34
Sample Name =	69 lb liner				East Coast		
Ring Crush, lbs	147.4	140.9	136.2	130.7	123.9	108.1	84.2
Std. Dev.	12.45	10.77	10.60	9.74	6.17	9.36	5.77
Ratio to 50%	1.127	1.078	1.042	1.000	0.948	0.827	0.644
STFI, lb/in	39.4	36.4	34.4	32.1	29.5	25.3	18.6
Std. Dev.	3.96	3.54	3.19	3.23	3.16	2.85	1.62
Ratio to 50%	1.225	1.133	1.069	1.000	0.919	0.787	0.580
Moisture, %	4.36	5.73	6.83	7.53	8.73	10.22	12.51

Effect of Relative Humidity on Ring Crush, STFI, and Moisture Content

Percent R.H.	20%	30 %	40 %	50 %	60%	70%	80%
Sample Name =	42 lb recycled liner East Coast						
Ring Crush, lbs	108.9	103.3	97.4	93.7	89.1	78.1	60.2
Std. Dev.	9.48	10.78	11.63	11.69	10.16	9.02	7.62
Ratio to 50%	1.162	1.102	1.039	1.000	0.951	0.833	0.643
STFI, lb/in	28.9	26.6	24.6	23.4	21.7	18.1	13.5
Std. Dev.	2.16	2.01	1.27	1.47	1.28	1.36	1.64
Ratio to 50%	1.233	1.138	1.051	1.000	0.928	0.774	0.577
Moisture, %	4.36	5.69	6.74	7.46	8.54	9.89	11.94
Sample Name =	42 lb recycled liner East Coast						
Ring Crush, lbs	97.0	91.6	88.2	82.9	78.8	70.2	56.9
Std. Dev.	4.81	3.78	3.15	3.61	2.84	3.32	2.40
Ratio to 50%	1.170	1.105	1.065	1.000	0.951	0.847	0.687
STFI, lb/in	25.3	23.7	22.1	21.5	19.4	16.3	12.3
Std. Dev.	2.46	1.98	1.46	1.72	1.12	1.16	1.02
Ratio to 50%	1.179	1.105	1.032	1.000	0.903	0.761	0.572
Moisture, %	4.43	5.70	6.79	7.58	8.67	10.03	12.06

Effect of Relative Humidity on Ring Crush, STFI, and Moisture Content

Percent R.H.	20%	30 %	40 %	50 %	60%	70%	80%
Sample Name =	HP-D (35 lb) liner				East Coast		
Ring Crush, lbs	93.4	90.8	85.6	84.2	77.4	67.6	58.1
Std. Dev.	9.24	5.42	5.10	6.57	4.85	4.62	3.74
Ratio to 50%	1.109	1.078	1.017	1.000	0.919	0.803	0.690
STFI, lb/in	30.8	29.9	27.3	25.7	22.3	20.8	14.5
Std. Dev.	2.90	2.31	2.67	1.69	1.72	1.47	1.39
Ratio to 50%	1.197	1.160	1.061	1.000	0.867	0.809	0.562
Moisture, %	4.41	5.81	6.80	7.76	8.90	10.43	12.49
Sample Name =	HP-D (35 lb) liner				East Coast		
Ring Crush, lbs	83.4	77.8	76.8	70.9	65.9	58.7	45.7
Std. Dev.	7.62	5.15	5.50	5.82	4.06	3.83	3.06
Ratio to 50%	1.177	1.099	1.084	1.000	0.930	0.829	0.646
STFI, lb/in	25.8	22.8	22.0	20.3	19.0	16.2	11.9
Std. Dev.	2.29	2.36	2.01	1.95	1.60	0.88	1.03
Ratio to 50%	1.267	1.121	1.082	1.000	0.932	0.794	0.587
Moisture, %	4.44	5.76	6.86	8.23	8.86	10.40	12.62
Sample Name =	HP-D (35 lb) liner				West Coast		
Ring Crush, lbs	80.1	75.8	69.2	67.2	63.3	56.4	47.5
Std. Dev.	5.65	6.11	8.16	3.84	4.45	3.91	3.55
Ratio to 50%	1.192	1.128	1.029	1.000	0.942	0.838	0.707
STFI, lb/in	24.6	21.6	20.5	18.8	16.7	15.1	11.6
Std. Dev.	2.06	1.99	1.63	2.13	1.82	1.45	1.10
Ratio to 50%	1.311	1.153	1.093	1.000	0.892	0.804	0.618
Moisture, %	4.18	5.46	6.50	7.42	8.60	9.97	11.88

Effect of Relative Humidity on Ring Crush, STFI, and Moisture Content

Percent R.H.	20%	30 %	40 %	50 %	60%	70%	80%
Sample Name = 26 lb medium West Coast							
Ring Crush, lbs	40.4	39.8	37.9	36.9	34.1	30.8	25.5
Std. Dev.	4.57	5.37	5.39	4.56	4.64	4.52	3.97
Ratio to 50%	1.095	1.079	1.028	1.000	0.925	0.834	0.691
STFI, lb/in	15.6	15.4	14.7	13.5	12.3	10.2	8.3
Std. Dev.	2.02	1.85	1.47	1.36	1.55	0.95	0.99
Ratio to 50%	1.158	1.138	1.092	1.000	0.913	0.757	0.612
Moisture, %	4.24	5.56	6.55	7.58	8.74	10.05	11.89
Sample Name = 26 lb medium East Coast							
Ring Crush, lbs	44.4	41.1	40.5	38.8	37.5	33.4	26.8
Std. Dev.	2.74	3.06	2.43	2.05	2.59	2.39	2.13
Ratio to 50%	1.145	1.059	1.044	1.000	0.968	0.862	0.692
STFI, lb/in	17.2	15.9	15.4	14.1	13.1	11.8	8.7
Std. Dev.	1.49	1.30	1.71	0.88	1.66	1.20	0.92
Ratio to 50%	1.217	1.128	1.092	1.000	0.931	0.840	0.617
Moisture, %	4.00	5.23	6.21	6.79	8.03	9.36	11.34
Sample Name = 26 lb medium East Coast							
Ring Crush, lbs	41.8	39.6	37.9	35.8	34.7	30.8	27.7
Std. Dev.	3.81	4.60	2.26	2.54	3.08	2.39	2.44
Ratio to 50%	1.167	1.106	1.060	1.000	0.968	0.862	0.775
STFI, lb/in	17.6	15.0	14.0	12.9	12.6	11.3	8.4
Std. Dev.	1.15	0.96	1.12	1.08	1.16	0.76	0.67
Ratio to 50%	1.362	1.167	1.084	1.000	0.974	0.878	0.654
Moisture, %	4.02	5.28	6.31	7.33	8.37	9.61	11.72
Sample Name = 26 lb medium East Coast							
Ring Crush, lbs	43.6	40.9	40.6	37.7	36.6	32.7	28.2
Std. Dev.	3.03	3.61	2.82	3.91	2.26	2.57	2.03
Ratio to 50%	1.159	1.087	1.078	1.000	0.973	0.868	0.748
STFI, lb/in	15.8	15.0	13.8	12.7	11.9	10.7	8.1
Std. Dev.	0.95	0.86	0.86	0.71	0.85	0.75	0.65
Ratio to 50%	1.249	1.182	1.089	1.000	0.940	0.841	0.641
Moisture, %	4.03	5.22	6.19	7.39	8.39	9.69	11.76

Effect of Relative Humidity on Ring Crush, STFI, and Moisture Content

Percent R.H.	20%	30 %	40 %	50 %	60%	70%	80%
Sample Name =	33 lb medium				East Coast		
Ring Crush, lbs	67.6	64.1	61.9	60.4	56.9	50.9	42.8
Std. Dev.	4.60	4.26	3.72	2.88	2.74	3.22	1.98
Ratio to 50%	1.118	1.061	1.025	1.000	0.941	0.842	0.709
STFI, lb/in	21.1	19.8	18.6	17.2	16.1	14.4	10.7
Std. Dev.	1.37	1.62	1.13	1.36	1.46	1.21	0.65
Ratio to 50%	1.232	1.156	1.087	1.000	0.940	0.842	0.623
Moisture, %	4.10	5.34	6.32	7.27	8.26	9.48	11.51
Sample Name =	33 lb medium				East Coast		
Ring Crush, lbs	58.2	54.1	50.6	47.4	46.0	41.9	33.8
Std. Dev.	3.74	3.72	3.91	5.00	3.61	3.50	2.62
Ratio to 50%	1.227	1.141	1.066	1.000	0.969	0.884	0.713
STFI, lb/in	20.4	18.7	17.2	15.9	15.6	13.5	10.1
Std. Dev.	1.62	1.60	1.71	1.43	0.94	1.11	0.85
Ratio to 50%	1.277	1.174	1.078	1.000	0.976	0.849	0.633
Moisture, %	4.12	5.46	6.53	7.65	8.69	9.91	11.84
Sample Name =	33 lb medium				East Coast		
Ring Crush, lbs	74.7	70.8	65.0	62.2	60.0	53.8	43.1
Std. Dev.	4.10	4.20	3.63	5.83	5.15	3.82	3.05
Ratio to 50%	1.201	1.139	1.046	1.000	0.965	0.865	0.694
STFI, lb/in	21.1	20.1	18.5	17.2	16.0	14.3	10.8
Std. Dev.	1.71	1.15	1.12	1.18	1.36	0.85	0.77
Ratio to 50%	1.228	1.170	1.078	1.000	0.931	0.828	0.630
Moisture, %	3.91	5.17	6.19	7.24	8.18	9.43	11.40

Effect of Relative Humidity on Ring Crush, STFI, and Moisture Content

Percent R.H.	20%	30 %	40 %	50 %	60%	70%	80%
Sample Name =	40 lb medium				East Coast		
Ring Crush, lbs	94.9	87.4	83.9	80.1	74.6	66.9	55.5
Std. Dev.	5.02	4.93	7.02	3.73	4.12	5.49	1.95
Ratio to 50%	1.184	1.092	1.047	1.000	0.931	0.836	0.692
STFI, lb/in	26.2	24.5	22.4	21.2	19.9	17.4	13.6
Std. Dev.	2.18	2.11	2.09	1.56	1.35	1.14	1.11
Ratio to 50%	1.235	1.156	1.057	1.000	0.936	0.818	0.639
Moisture, %	3.96	5.29	6.34	7.34	8.27	9.47	11.38
Sample Name =	40 lb medium				West Coast		
Ring Crush, lbs	87.1	82.6	75.6	72.9	69.7	60.9	48.6
Std. Dev.	4.53	4.64	5.36	3.76	3.80	4.46	2.29
Ratio to 50%	1.196	1.134	1.038	1.000	0.957	0.836	0.667
STFI, lb/in	24.5	22.6	21.4	20.6	18.4	17.0	13.7
Std. Dev.	2.61	2.50	1.80	1.39	2.20	1.59	1.42
Ratio to 50%	1.190	1.096	1.038	1.000	0.891	0.822	0.666
Moisture, %	3.91	5.26	6.47	7.61	8.65	9.82	11.90
Sample Name =	40 lb medium				East Coast		
Ring Crush, lbs	94.1	90.1	85.9	78.9	76.6	74.7	61.5
Std. Dev.	4.67	4.29	4.19	3.75	3.75	4.16	5.07
Ratio to 50%	1.194	1.142	1.089	1.000	0.972	0.947	0.780
STFI, lb/in	27.8	25.5	23.3	22.1	20.4	18.3	13.7
Std. Dev.	1.79	1.69	1.43	1.54	1.47	1.01	0.86
Ratio to 50%	1.258	1.153	1.057	1.000	0.921	0.828	0.622
Moisture, %	3.82	5.22	6.26	7.17	8.09	9.36	11.44

Effect of Relative Humidity on Ring Crush, STFI, and Moisture Content

Percent R.H.	20%	30 %	40 %	50 %	60%	70%	80%
Sample Name =	26 lb recycled medium East Coast						
Ring Crush, lbs	42.3	40.0	36.9	35.3	31.4	28.2	22.4
Std. Dev.	3.70	2.70	3.19	2.29	2.50	2.30	1.59
Ratio to 50%	1.200	1.133	1.047	1.000	0.890	0.799	0.636
STFI, lb/in	14.9	12.8	12.0	11.1	9.8	8.2	6.4
Std. Dev.	1.52	1.49	1.11	0.98	1.02	0.93	0.53
Ratio to 50%	1.349	1.156	1.080	1.000	0.885	0.740	0.577
Moisture, %	4.27	5.67	6.81	7.72	8.95	10.48	12.97
Sample Name =	26 lb recycled medium West Coast						
Ring Crush, lbs	42.1	39.5	37.8	34.9	32.2	29.0	24.8
Std. Dev.	4.41	5.73	5.05	5.03	4.08	3.51	3.67
Ratio to 50%	1.209	1.134	1.085	1.000	0.923	0.833	0.713
STFI, lb/in	15.1	14.5	13.5	12.6	11.5	10.0	7.6
Std. Dev.	1.74	1.47	1.74	1.28	1.32	0.91	0.64
Ratio to 50%	1.196	1.146	1.070	1.000	0.909	0.793	0.598
Moisture, %	4.27	5.72	6.74	7.83	8.86	10.14	12.21
Sample Name =	26 lb recycled medium East Coast						
Ring Crush, lbs	44.0	41.9	38.4	37.6	35.8	30.8	27.6
Std. Dev.	3.38	2.80	4.07	3.45	2.69	6.40	2.08
Ratio to 50%	1.172	1.115	1.021	1.000	0.952	0.821	0.735
STFI, lb/in	16.6	15.5	14.7	13.6	12.6	10.7	8.4
Std. Dev.	1.34	1.33	0.97	1.00	0.77	0.81	0.67
Ratio to 50%	1.221	1.140	1.082	1.000	0.928	0.791	0.622
Moisture, %	4.31	5.55	6.68	7.82	8.83	10.09	11.91

Effect of Relative Humidity on Ring Crush, STFI, and Moisture Content

Percent R.H.	20%	30 %	40 %	50 %	60%	70%	80%
Sample Name =	26 lb green liquor med. East Coast						
Ring Crush, lbs	49.0	47.8	45.0	43.4	41.9	37.9	33.0
Std. Dev.	6.15	7.39	5.77	6.22	6.86	6.04	4.79
Ratio to 50%	1.128	1.100	1.035	1.000	0.964	0.873	0.759
STFI, lb/in	19.1	17.1	16.5	15.0	14.6	12.7	9.7
Std. Dev.	1.92	1.65	1.27	1.35	1.26	0.93	0.96
Ratio to 50%	1.272	1.142	1.099	1.000	0.974	0.844	0.645
Moisture, %	3.94	5.14	6.31	7.47	8.49	9.45	11.15
Sample Name =	26 lb green liquor med. East Coast						
Ring Crush, lbs	45.1	42.5	41.7	38.6	35.8	31.8	27.0
Std. Dev.	3.36	2.66	3.04	2.54	2.96	6.49	1.95
Ratio to 50%	1.169	1.100	1.081	1.000	0.927	0.823	0.699
STFI, lb/in	15.6	14.5	13.9	13.3	12.2	11.1	9.0
Std. Dev.	1.01	0.99	1.18	0.95	1.23	0.71	2.36
Ratio to 50%	1.171	1.089	1.045	1.000	0.915	0.829	0.678
Moisture, %	4.02	5.24	6.28	7.25	8.14	9.40	11.51

Effect of Relative Humidity on Ring Crush, STFI, and Moisture Content

Percent R.H.	20%	30 %	40 %	50 %	60%	70%	80%
Sample Name =	HP-R (23 lb) medium				West Coast		
Ring Crush, lbs	48.3	46.3	44.8	41.9	40.4	38.0	32.2
Std. Dev.	5.43	4.27	3.28	4.33	3.79	3.05	2.20
Ratio to 50%	1.152	1.104	1.067	1.000	0.963	0.905	0.769
STFI, lb/in	19.3	16.2	15.0	14.1	13.2	12.0	9.3
Std. Dev.	1.84	1.55	1.03	1.22	0.95	0.97	0.84
Ratio to 50%	1.367	1.150	1.065	1.000	0.937	0.851	0.658
Moisture, %	4.29	5.52	6.64	7.53	8.74	10.18	12.24
Sample Name =	HP-R (23 lb) medium				East Coast		
Ring Crush, lbs	37.5	37.3	35.4	33.9	30.7	28.0	24.0
Std. Dev.	1.96	2.51	2.60	2.29	2.95	1.75	1.89
Ratio to 50%	1.108	1.103	1.046	1.000	0.908	0.827	0.709
STFI, lb/in	17.0	15.2	14.7	14.1	12.9	11.3	8.7
Std. Dev.	1.62	1.53	1.41	1.24	1.30	1.04	1.03
Ratio to 50%	1.200	1.071	1.038	1.000	0.909	0.799	0.613
Moisture, %	4.03	5.25	6.36	7.42	8.33	9.57	11.56
Sample Name =	HP-R (23 lb) medium				West Coast		
Ring Crush, lbs	85.3	78.8	73.9	72.9	67.7	59.9	50.3
Std. Dev.	5.35	7.06	6.24	5.17	4.38	5.68	3.97
Ratio to 50%	1.171	1.080	1.013	1.000	0.928	0.821	0.690
STFI, lb/in	24.1	24.7	22.3	21.1	18.4	16.8	13.1
Std. Dev.	2.19	1.28	2.11	2.56	1.68	1.00	1.33
Ratio to 50%	1.142	1.170	1.057	1.000	0.873	0.795	0.619
Moisture, %	4.22	5.31	6.41	7.41	8.33	9.94	10.78